# Chandra/XMM high-resolution spectroscopy

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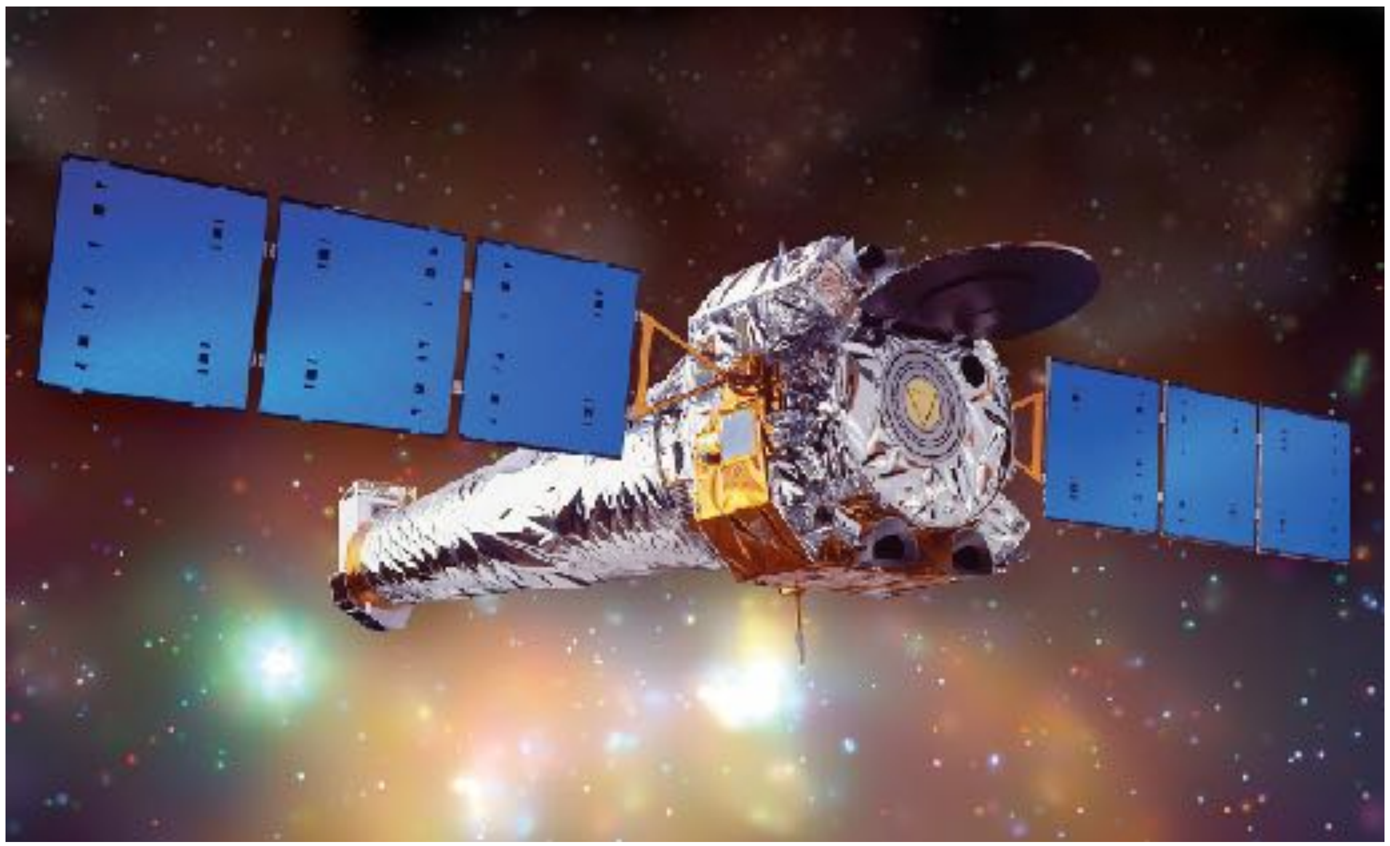
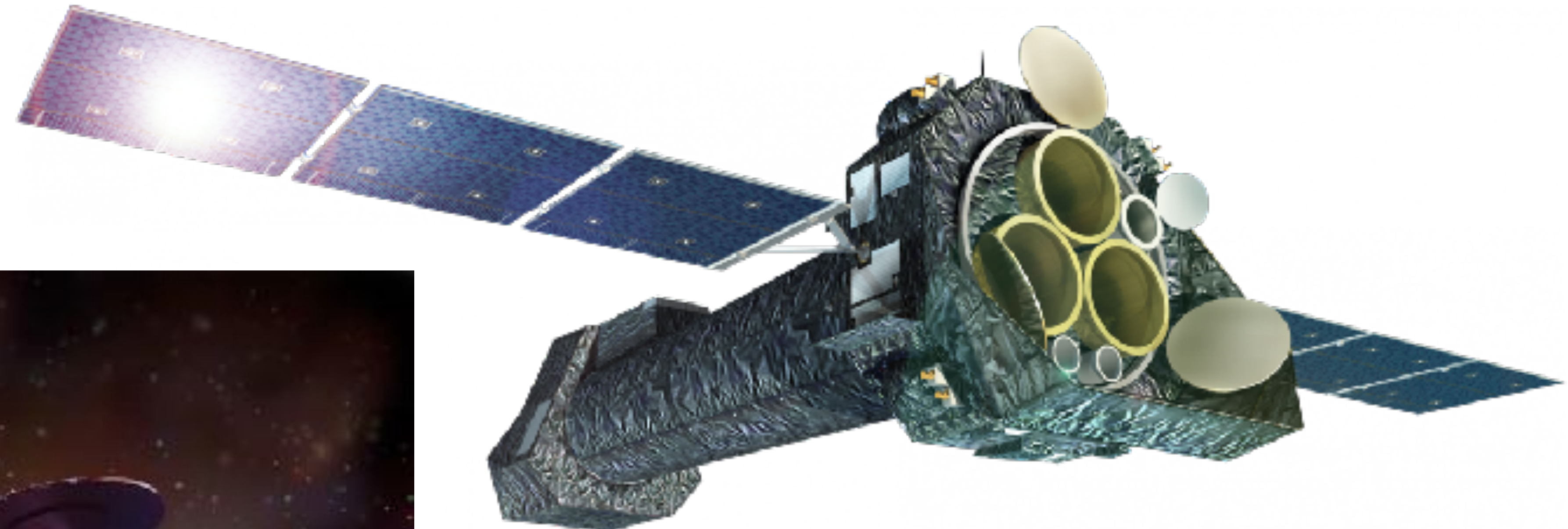
# Outline

1. Chandra/XMM-Newton Overview
2. spectroscopic principle of gratings
3. properties of gratings on Chandra/XMM
4. comparison between gratings and CCDs on spectroscopy
5. scientific research examples
6. conclusion

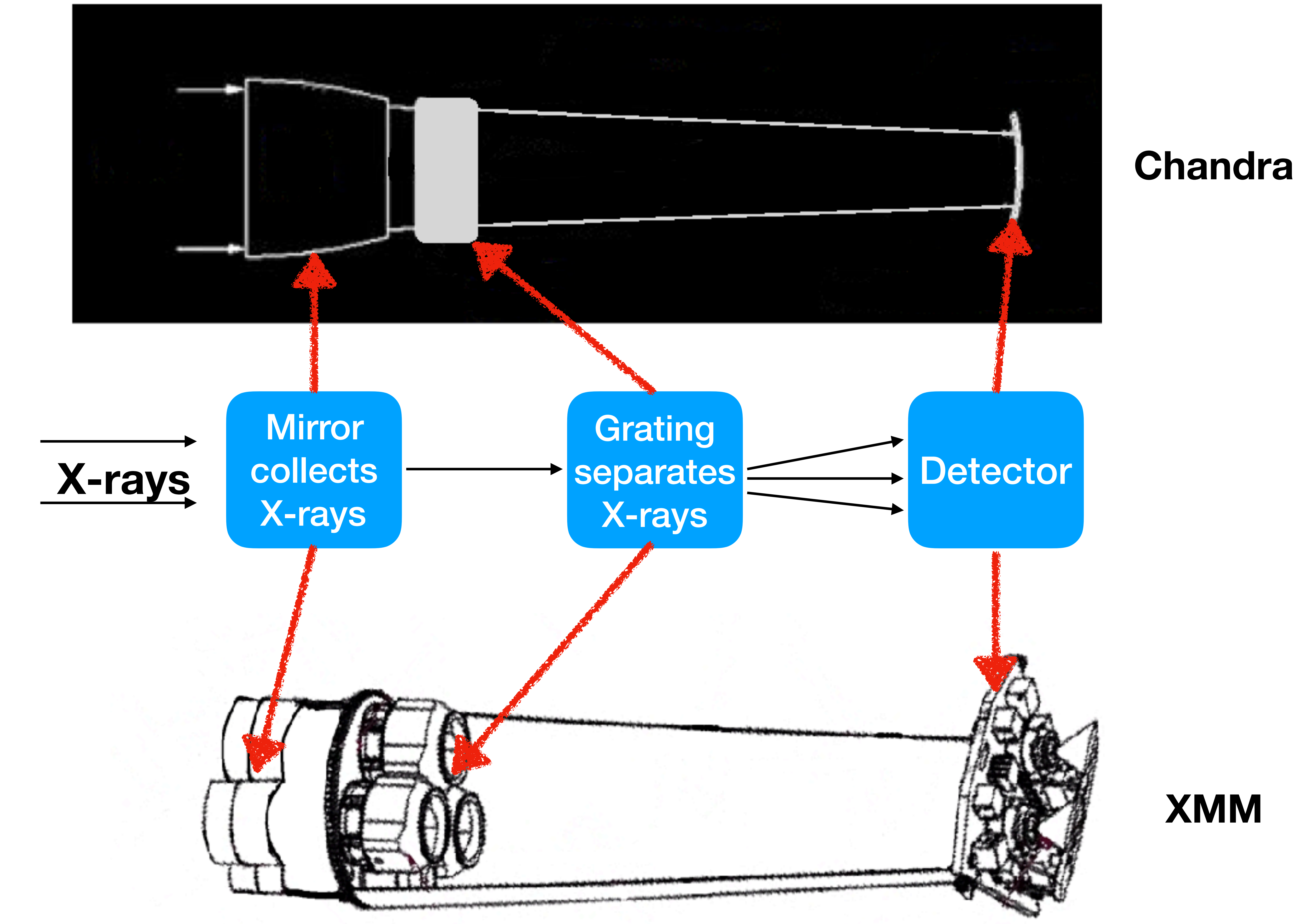
## Chandra





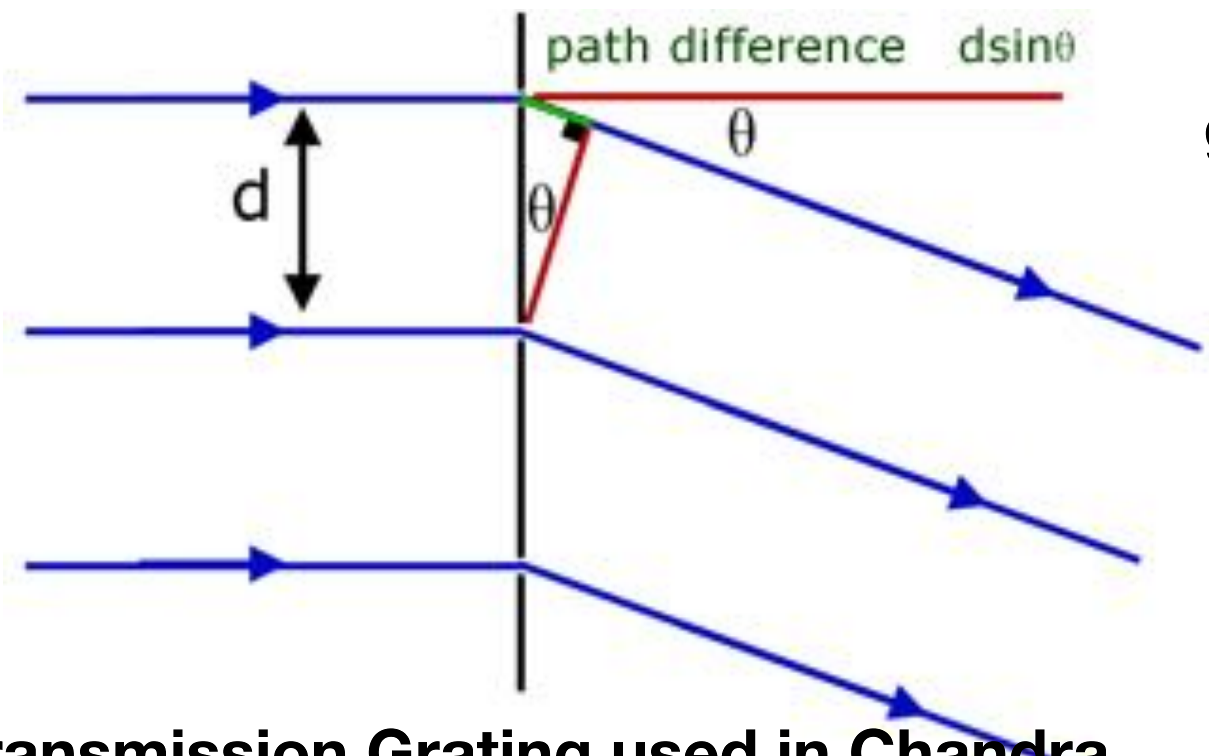
## XMM-Newton

| | Chandra | XMM-Newton |
|---|---|---|
| Launch time | July 23, 1999 | December 10, 1999 |
| orbit | 63.5 hr elliptical, geocentric | 48 hr elliptical, geocentric |
| wavelength | 0.1-10keV | 0.1-12keV |


Chandra
X-rays
Mirror collects X-rays
Grating separates X-rays
Detector
XMM

# Grating

**path difference = a whole number of wavelengths**
**—> waves of light add**

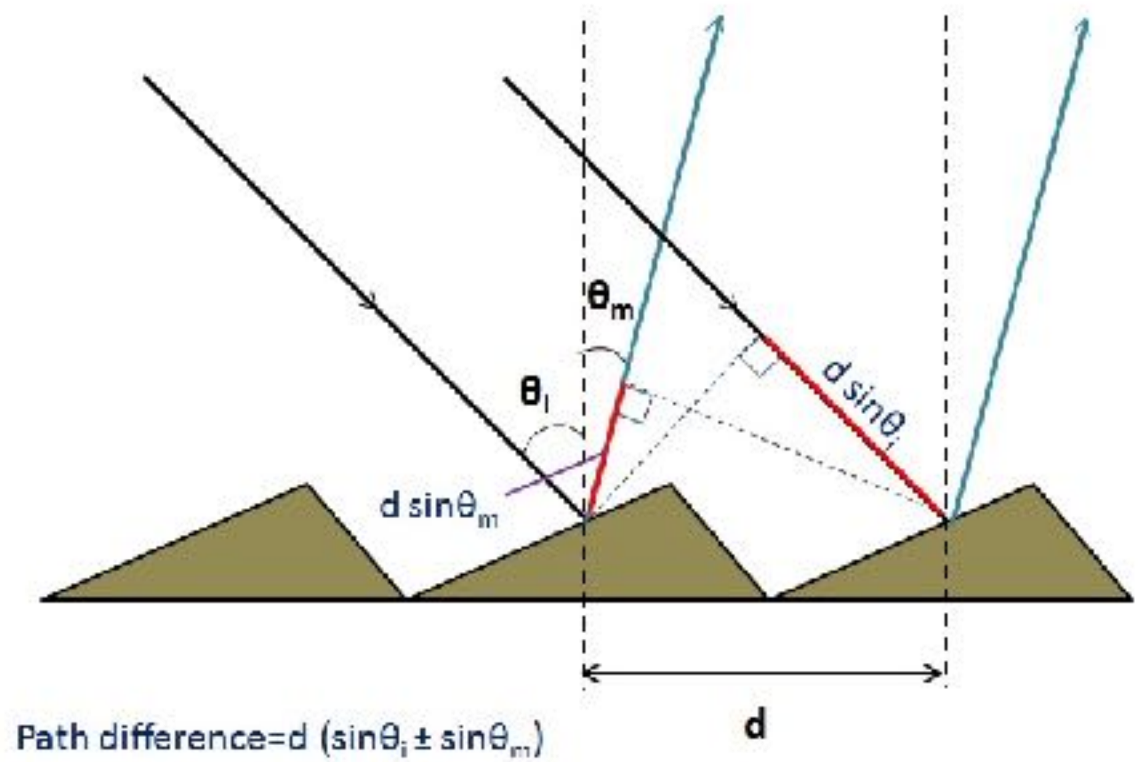



**Transmission Grating used in Chandra**

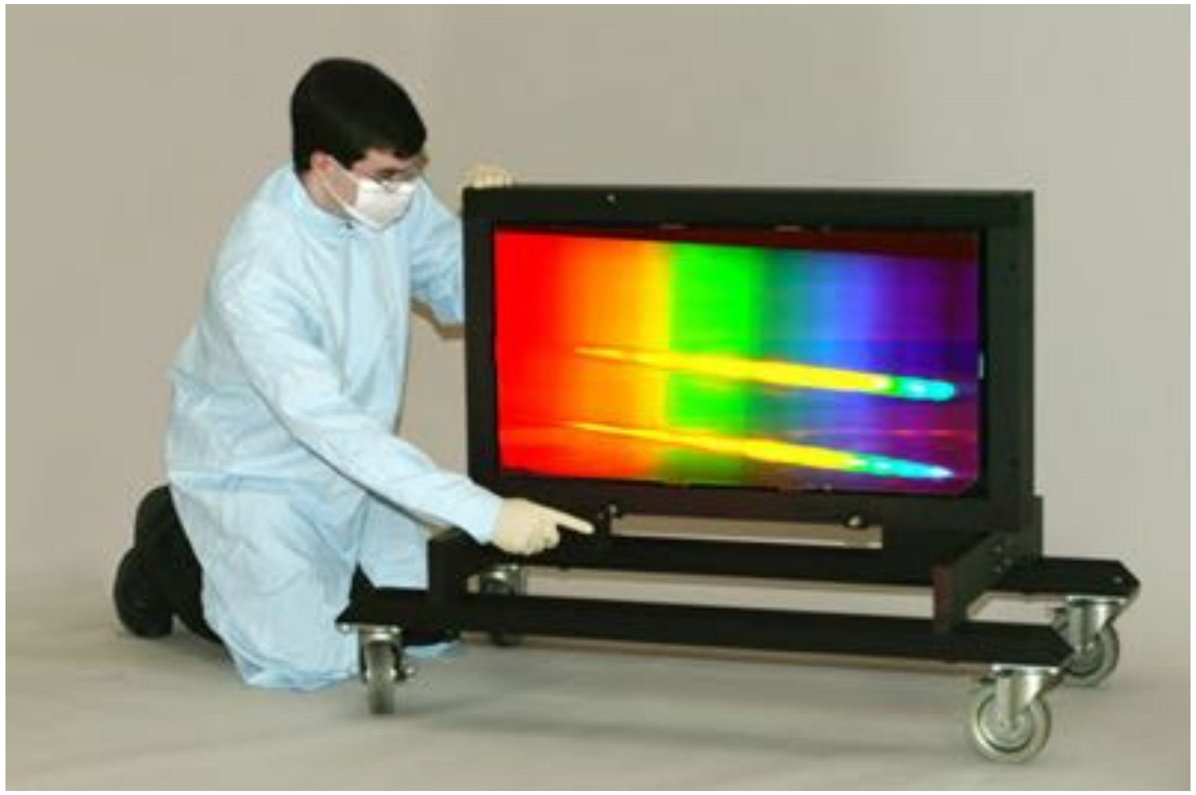
**grating equation**

$$d \sin \theta = n\lambda$$

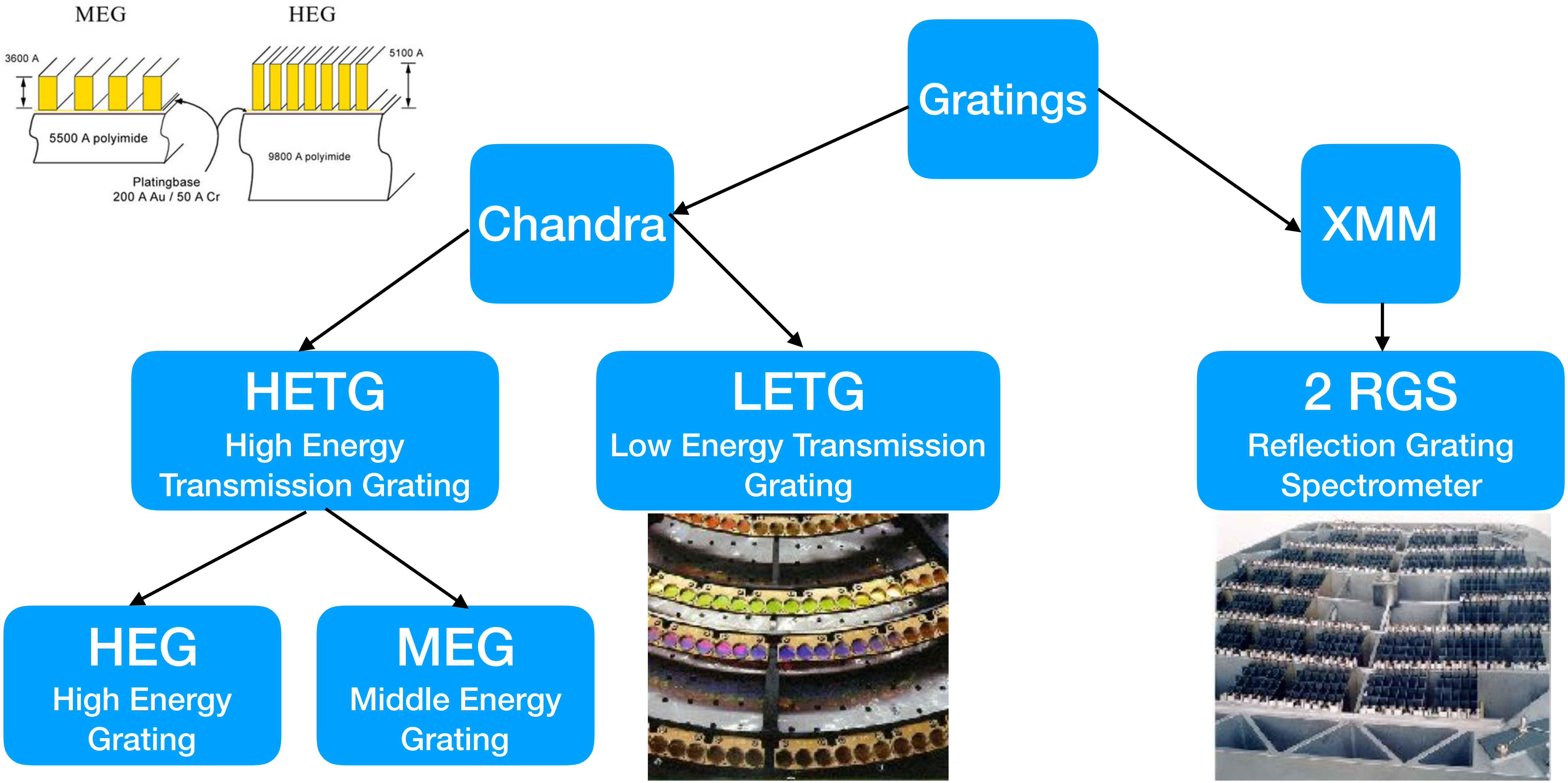
**d — grating spacing**
**θ — diffraction angle**
**n — integer number**
**λ — wavelength**




**Reflection Grating used in XMM-Newton**

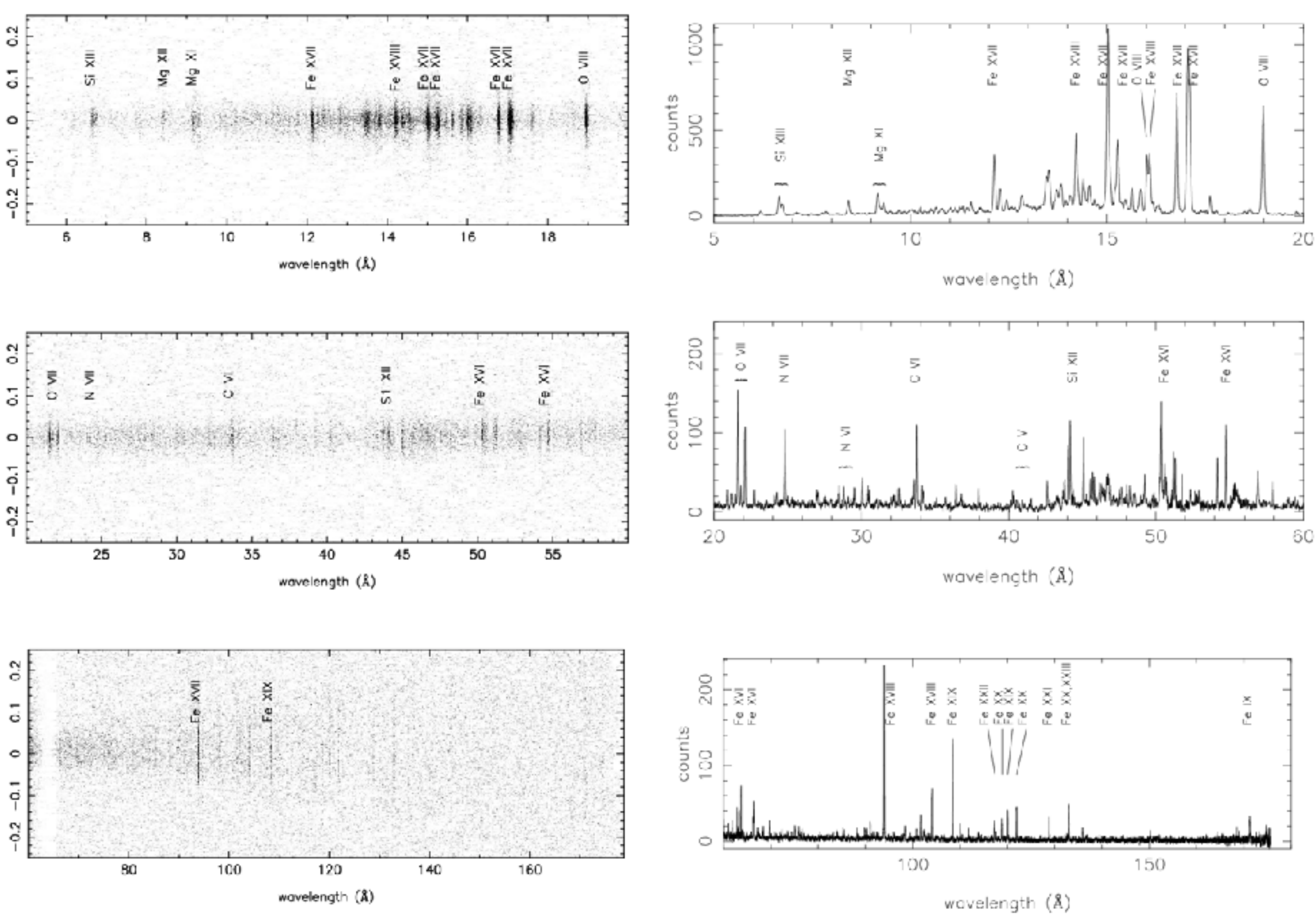


**light of different wavelength is separated**




| | Chandra | | | XMM-Newton | |
|---|---|---|---|---|---|
| | LETG | HETG | | RGS 1 | RGS 2 |
| | | MEG | HEG | | |
| **Energy Range** | 0.07-0.2keV | 0.4-5keV | 0.8-10keV | 0.35-2.5keV | |
| **Resolution(Δλ,FWHM)** | 0.05A | 0.023A | 0.012A | 0.060A | 0.070A |
| **Resolving Power(λ/Δλ)** | >=1000(0.077-0.248keV) | 660 at 0.826keV | 1000 at 1keV | 250 at 0.826keV | 214 at 0.826keV |

# Chandra/spectroscopy through LETG



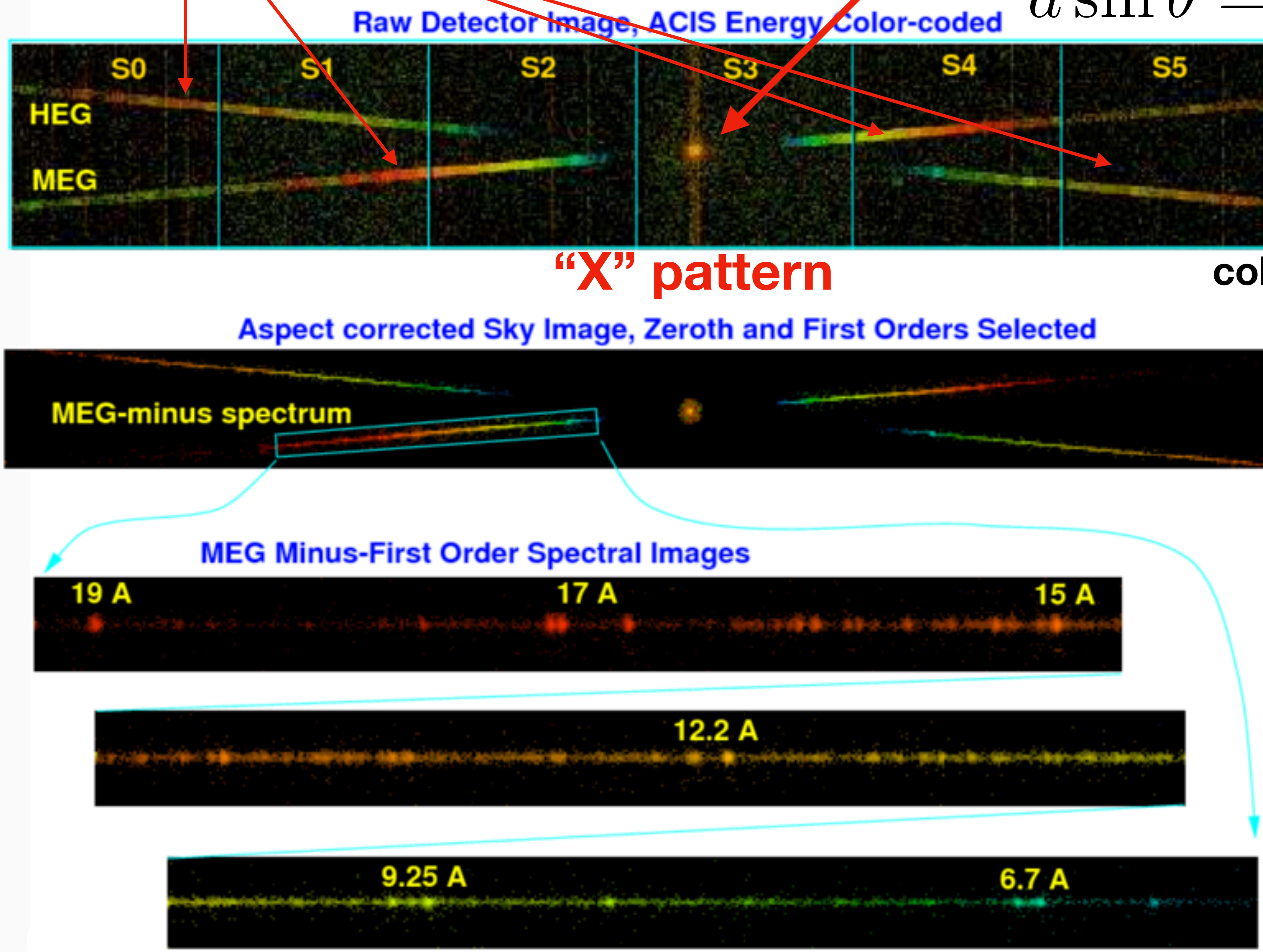

Extracted LETGS spectrum of Capella with some line identifications (from Brinkman et al. 2000, ApJ, 530, L111)

# Chandra/spectroscopy through HETG

first-order images; minus and plus

zero-order image: no dispersion

$$d \sin\theta = n\lambda$$




color: X-ray energy

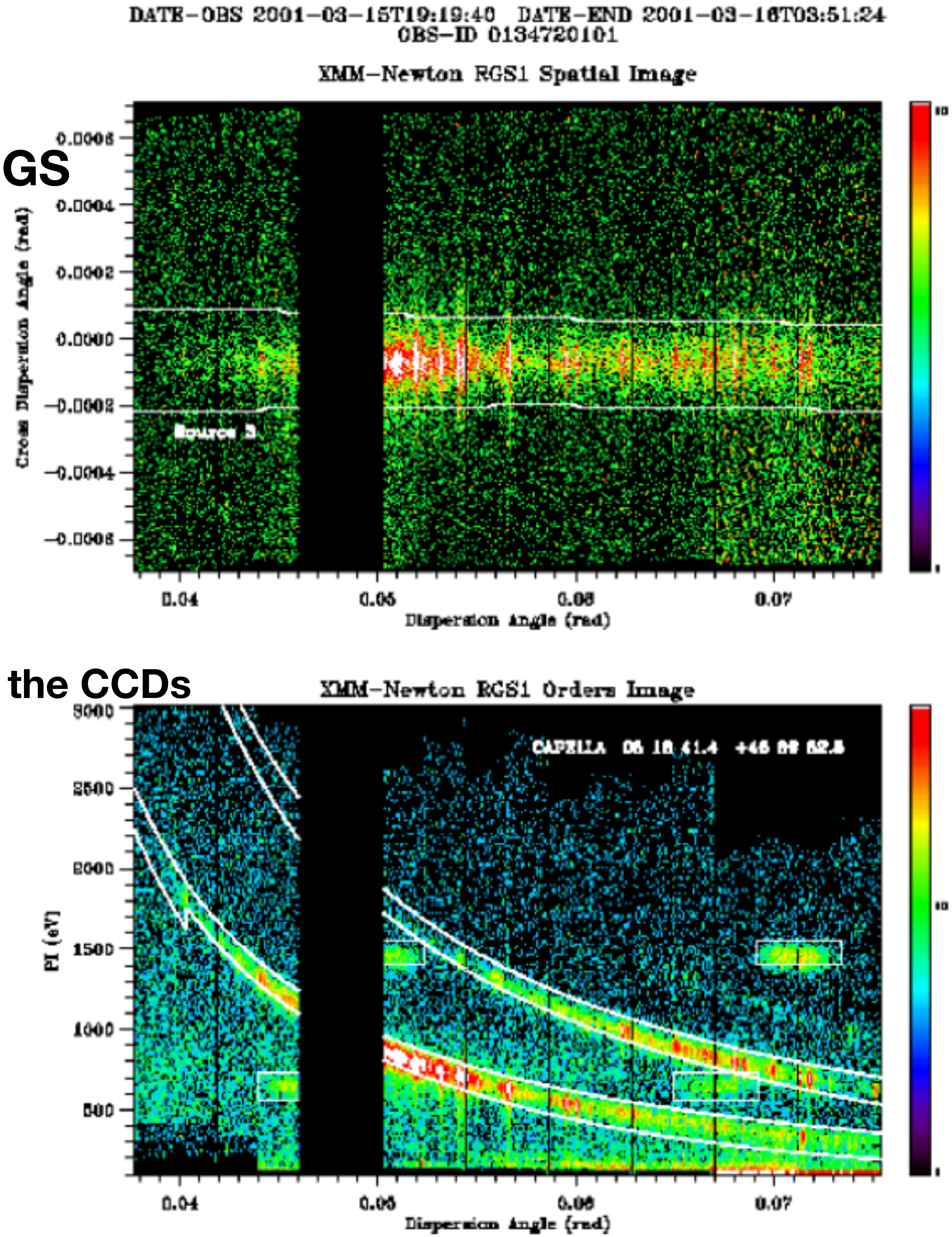
emission line is clearly visible

# XMM-Newton spectroscopy through RGS

$$d \sin\theta = n\lambda$$

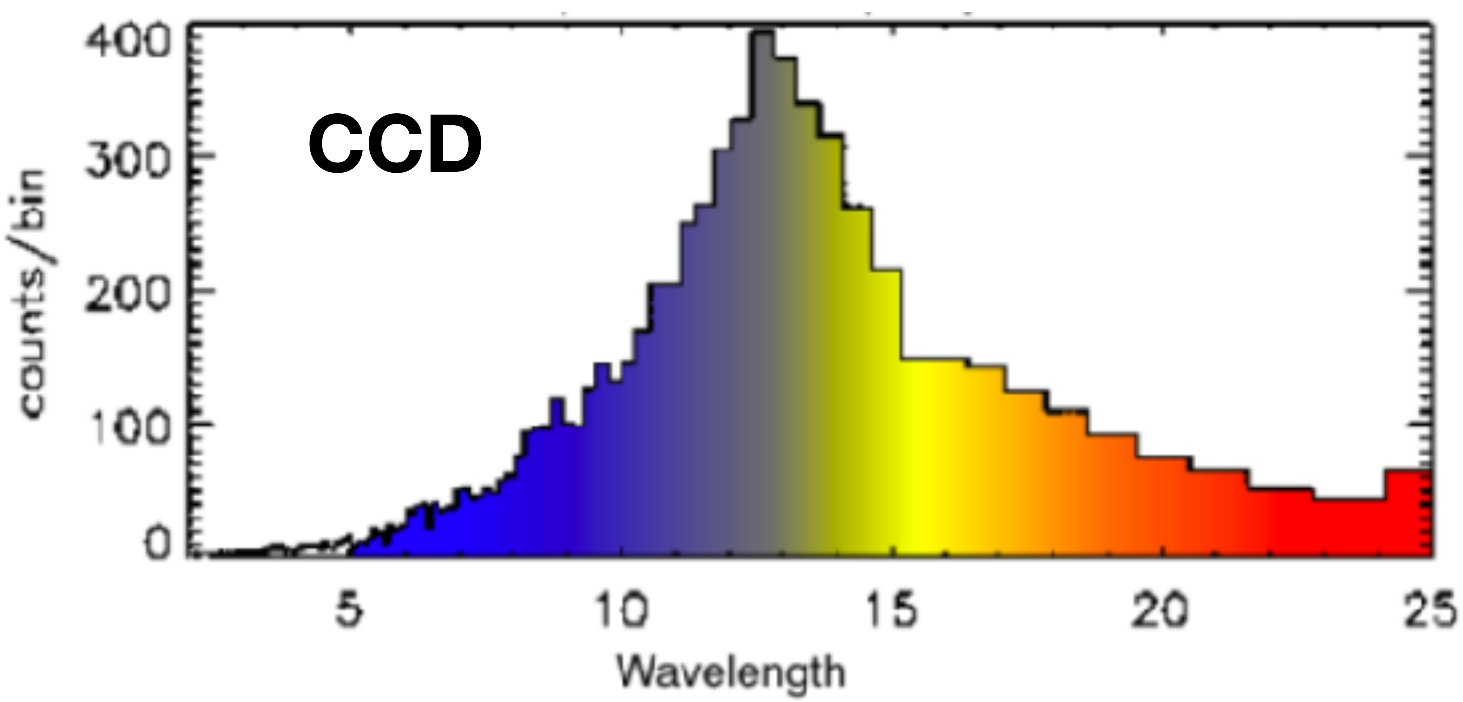
**diffraction equation —>**
**orders overlap on the CCD**

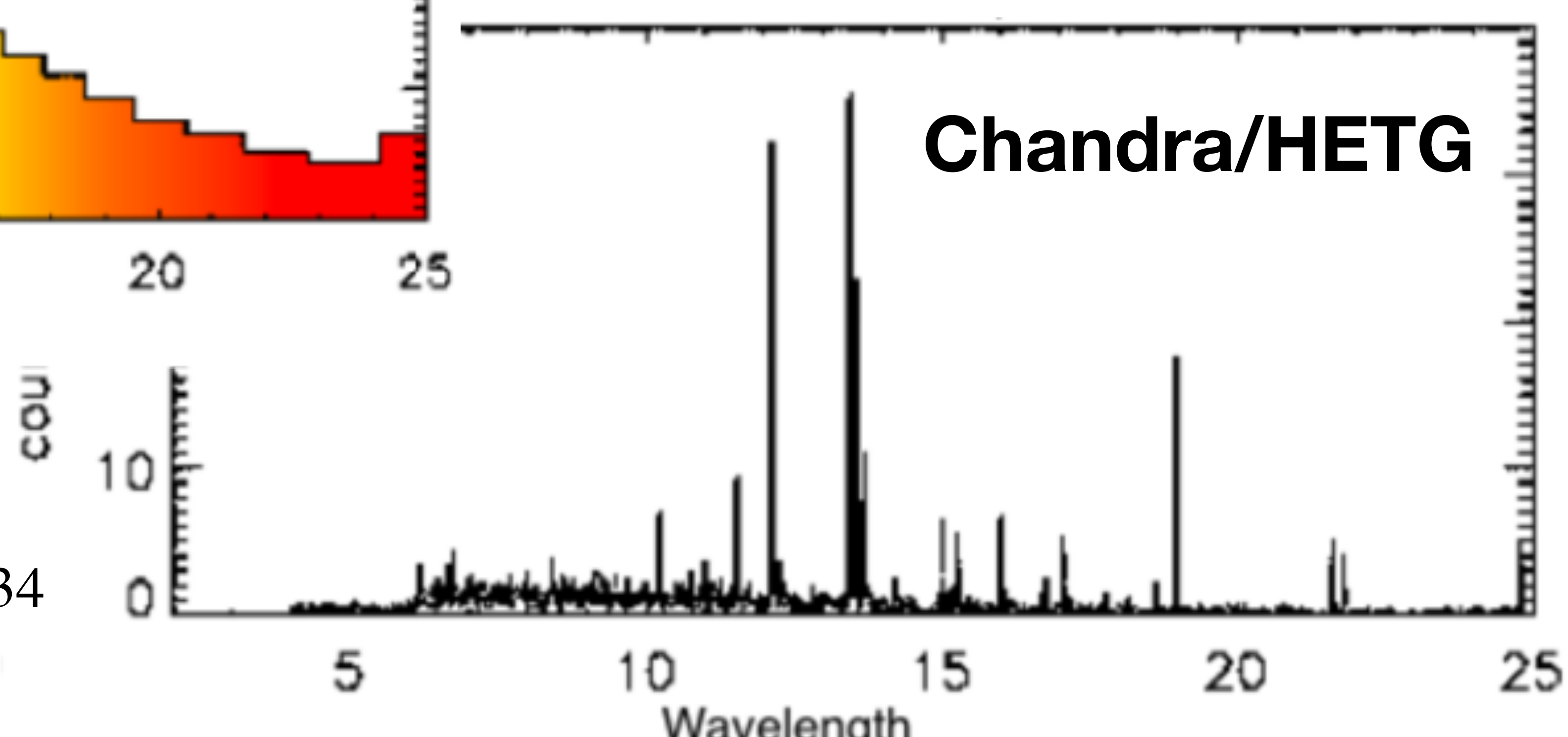
**intrinsic energy resolution of the CCDs**
**160 eV FWHM at 2 keV**



# Comparison between energy/wavelength resolving power of Grating and CCD

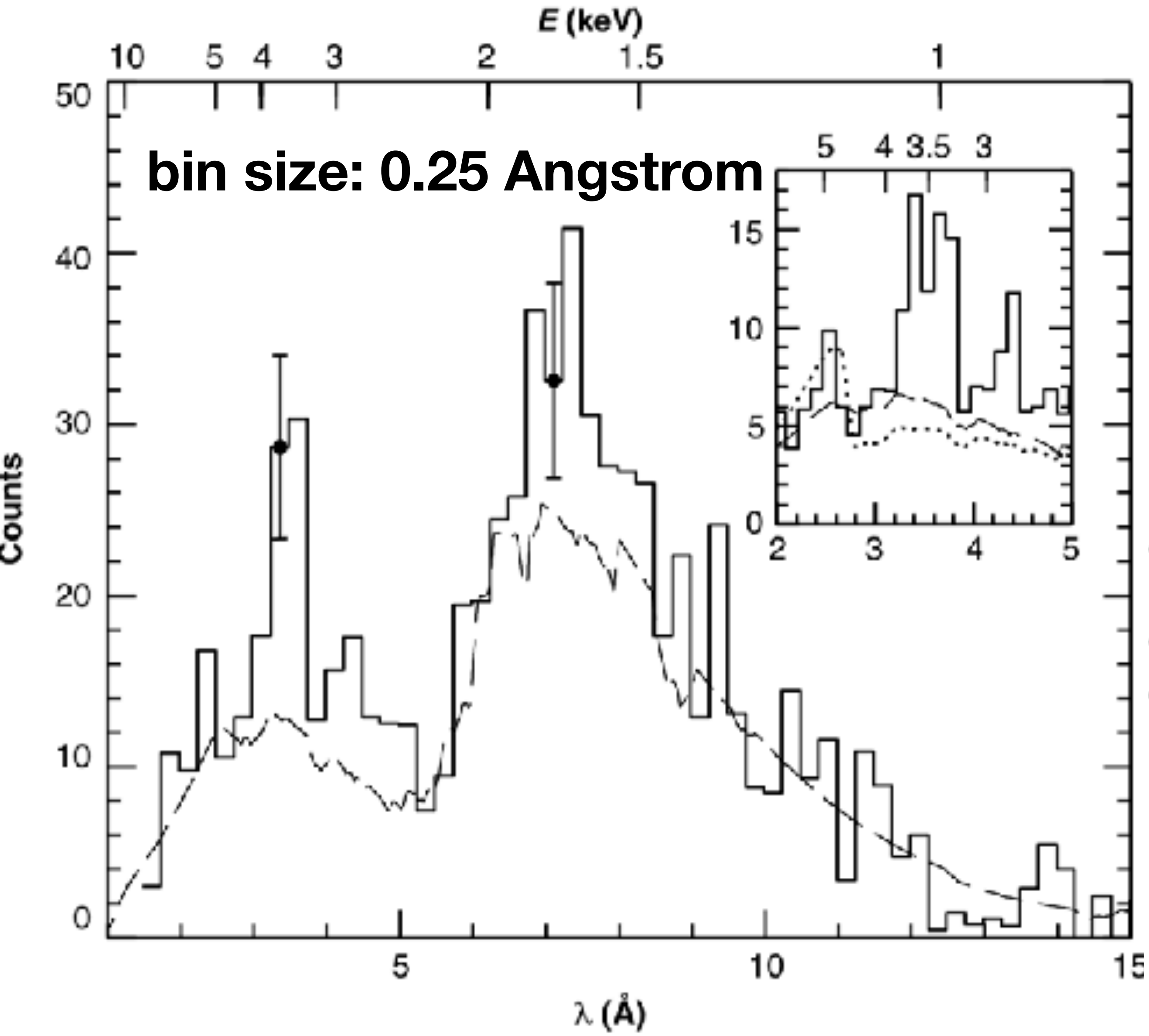
| Resolving Power(λ/Δλ) | | | | | |
|---|---|---|---|---|---|
| Gratings | | | | CCD | |
| LETG | HETG | | RGS | | |
| | MEG | HEG | | Chandra/ACIS | XMM/CCDs |
| >=1000(0.077-0.248keV) | 660 at 0.826keV | 1000 at 1keV | 250 at 0.826keV | ~15 at 2keV | 12.5 at 2keV |

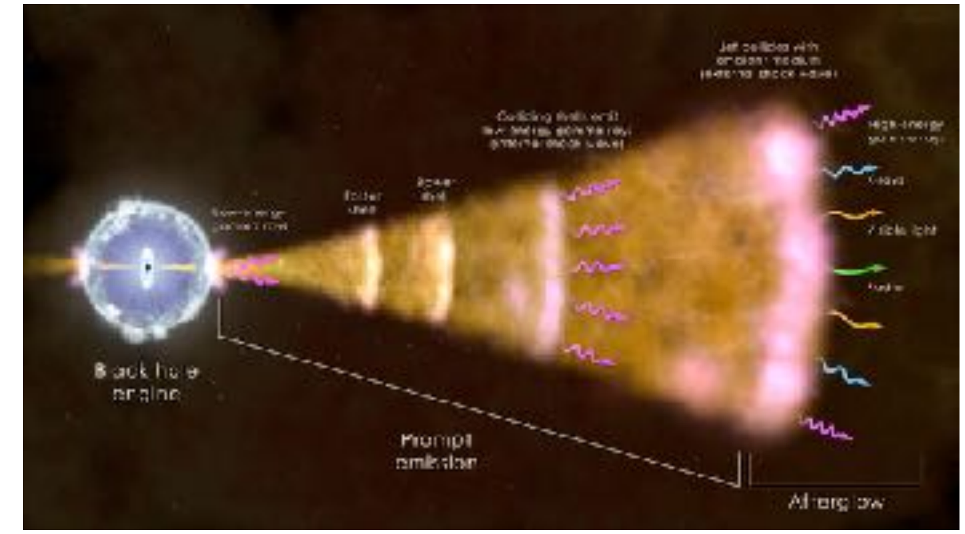


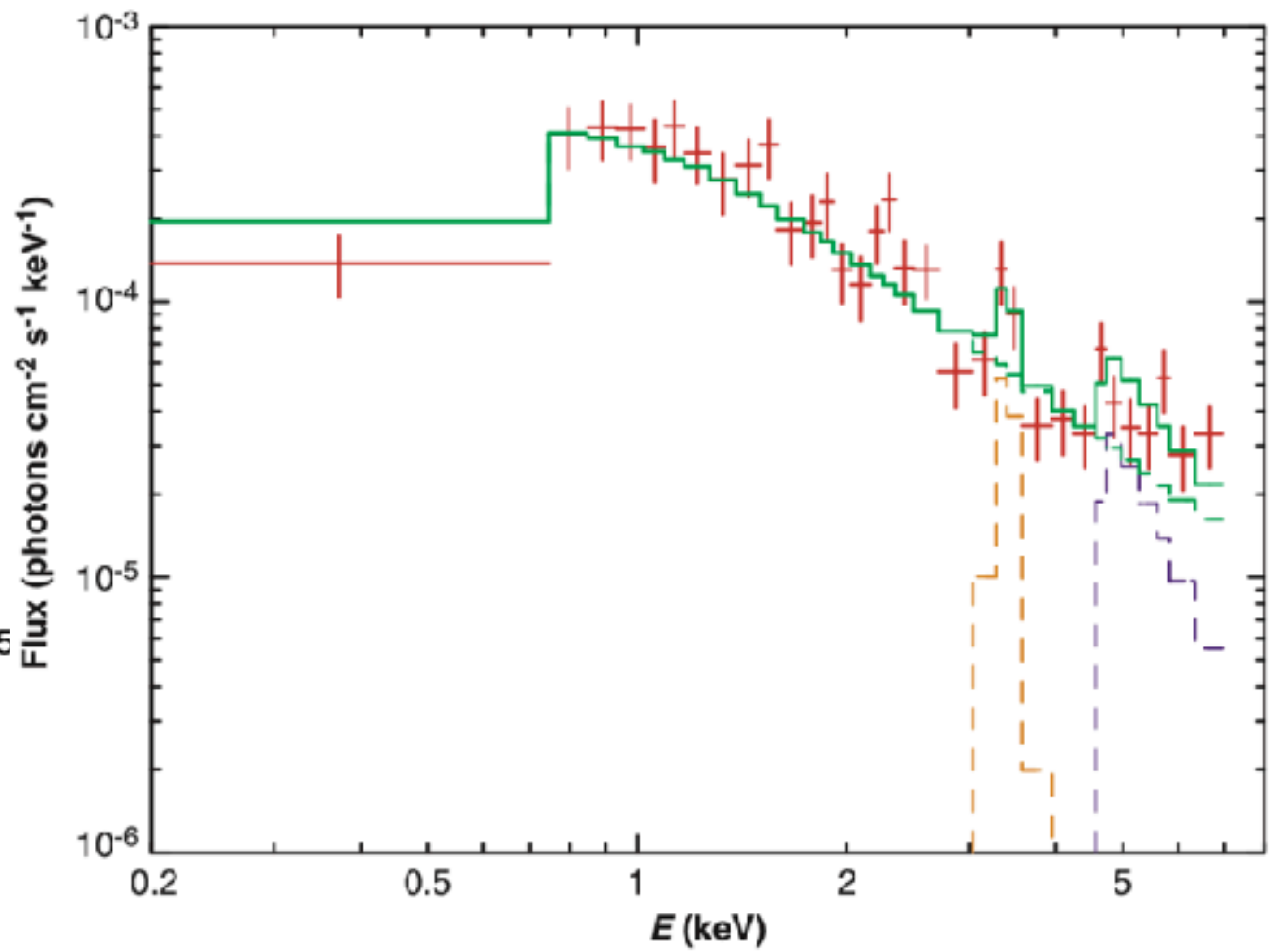




Adapted from Kastner et al. 2002, ApJ,567,434

## Observation of X-ray Lines from a GRB(GRB991216): Evidence of Moving Ejecta from the Progenitor



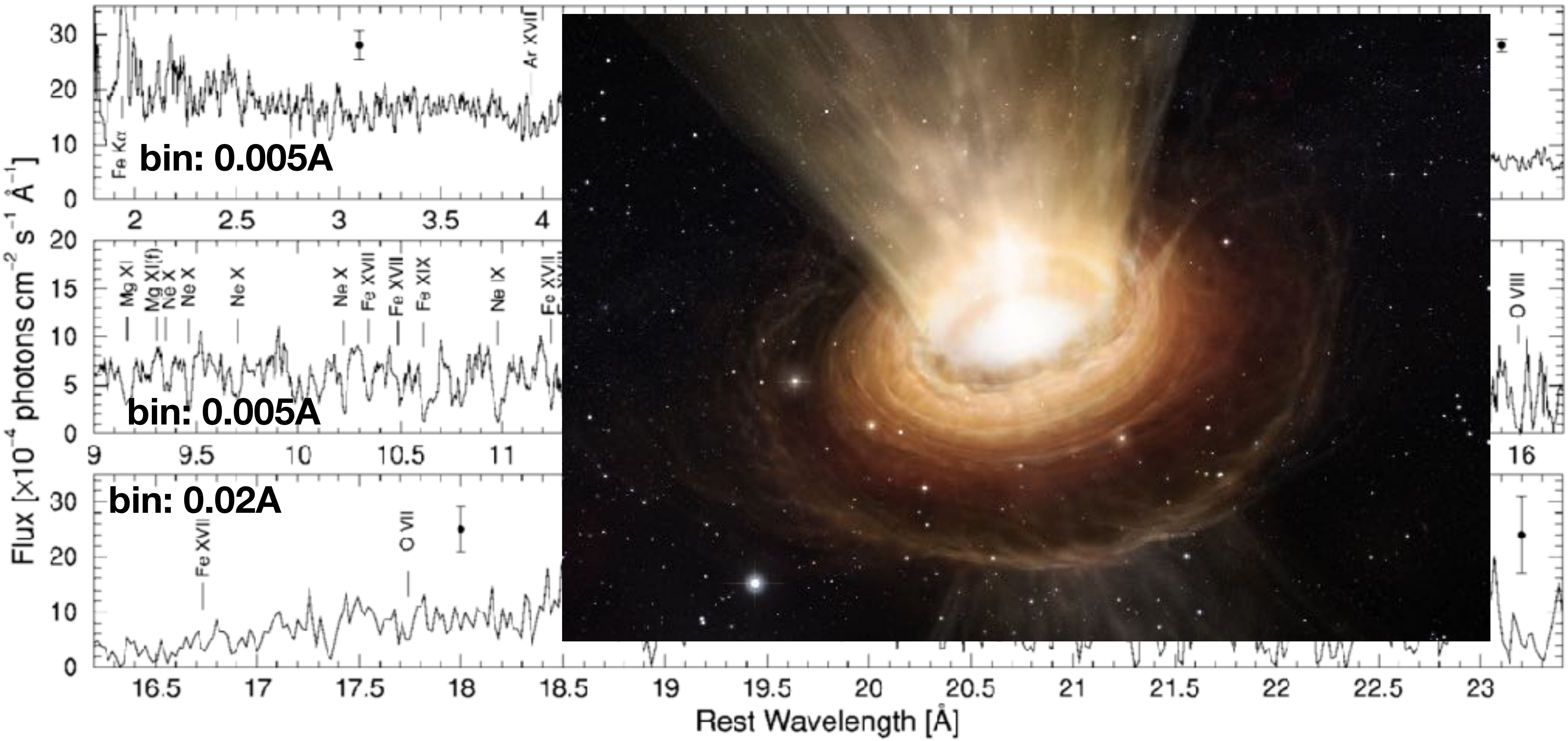

**first time**
**X-ray emission lines**
**from afterglow of GRB**

**~0.01Msun iron**
**~0.1c**
**Progenitor: Massive star**
**SN explosion**

**Piro, et al., 2000, Science**

# Discovery of Narrow X-ray Absorption Lines from NGC 3783 with the Chandra HEG Spectrometer

Kaspi et al. 2000 ApJ




**most detailed X-ray spectrum**

**of a galaxy with an active BH**

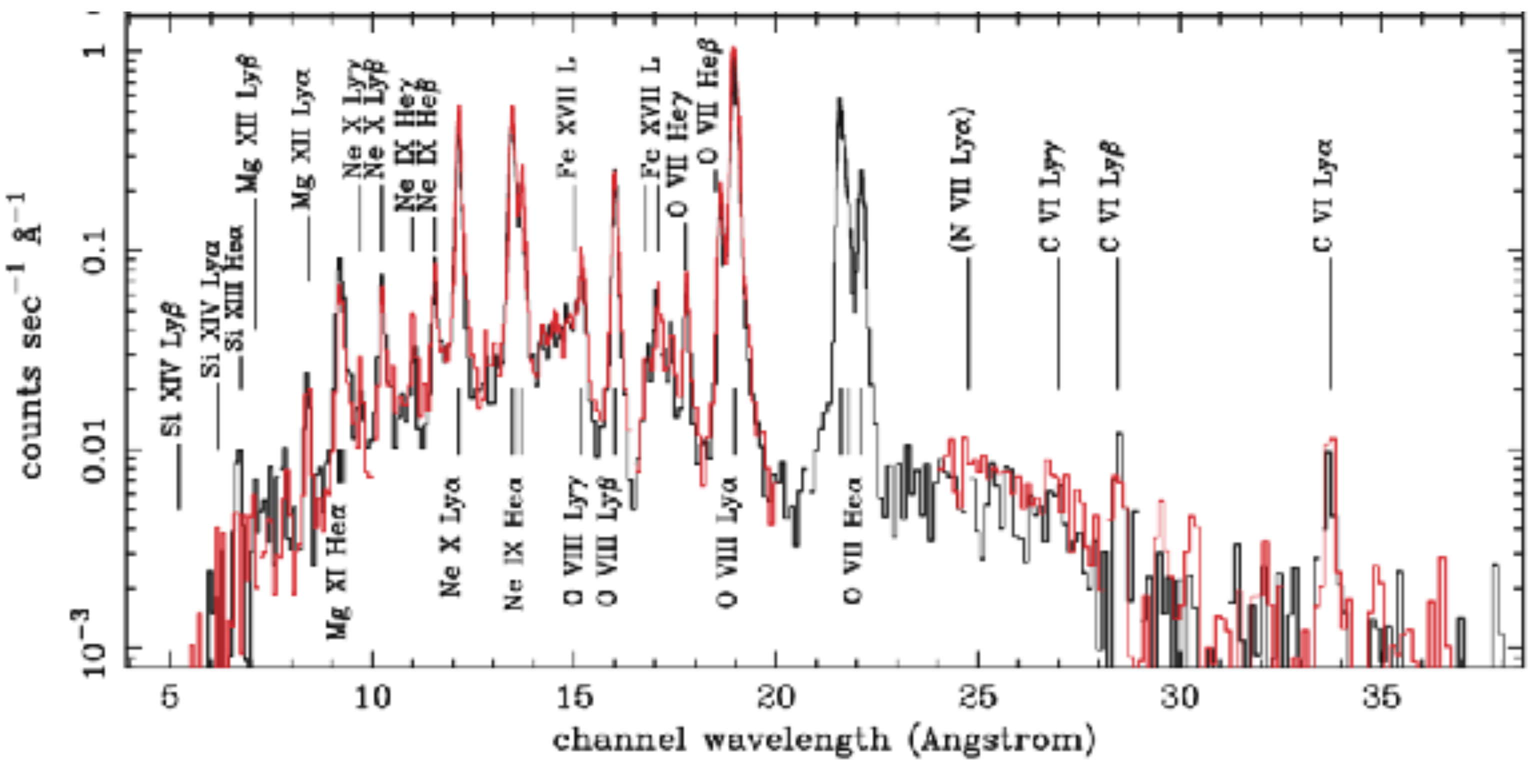
**composition, velocity, temperature,...**

**mean velocity(blueshifted): 440+-200km/s**

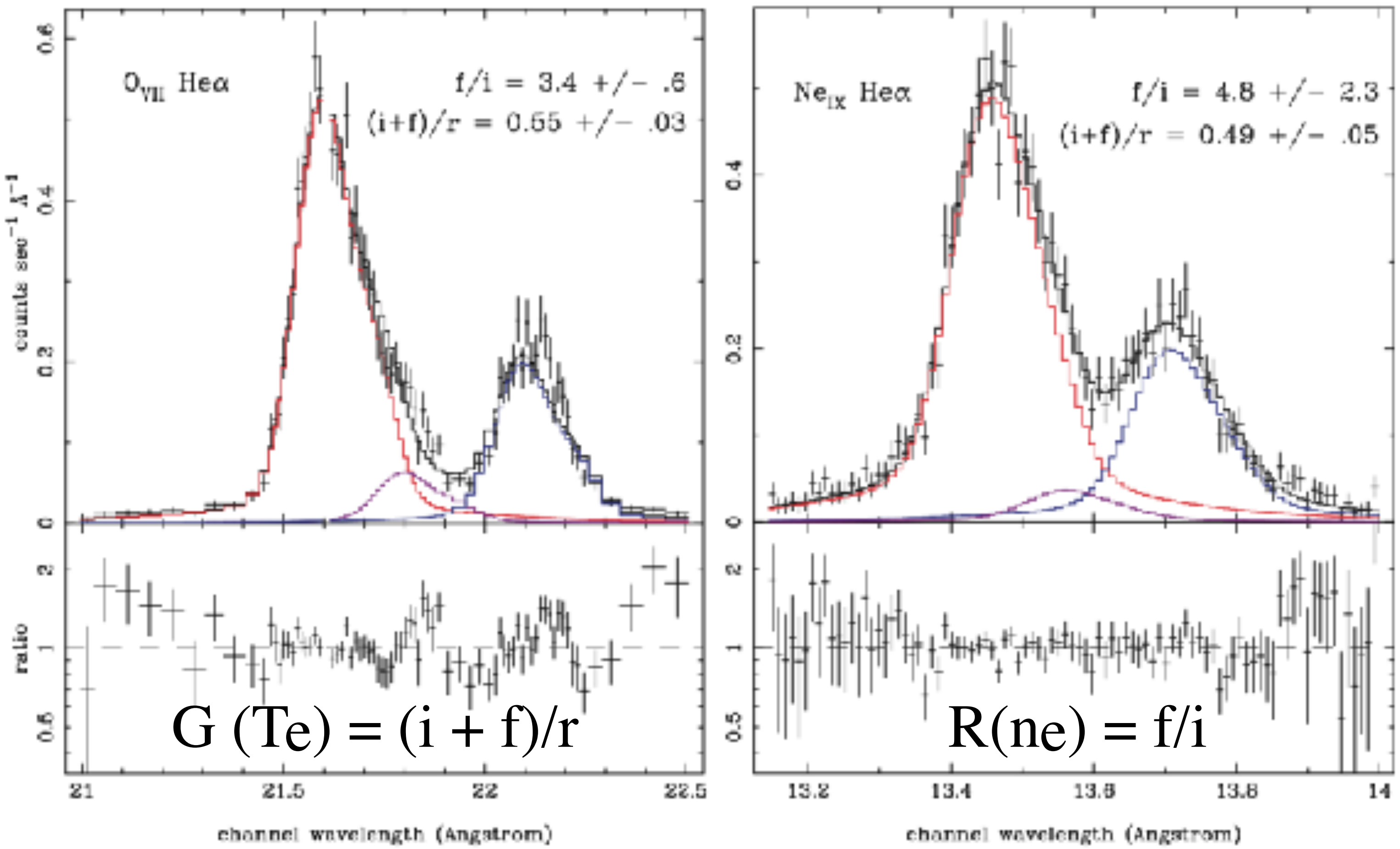
**warm absorbing gas outside broad-line region**

# The X-ray Spectrum of the SuperNova Remnant 1E 0102.2—7219

Rasmussen et al. 2001 A&A




**the most detailed soft X-ray spectrum of entire SNRs**

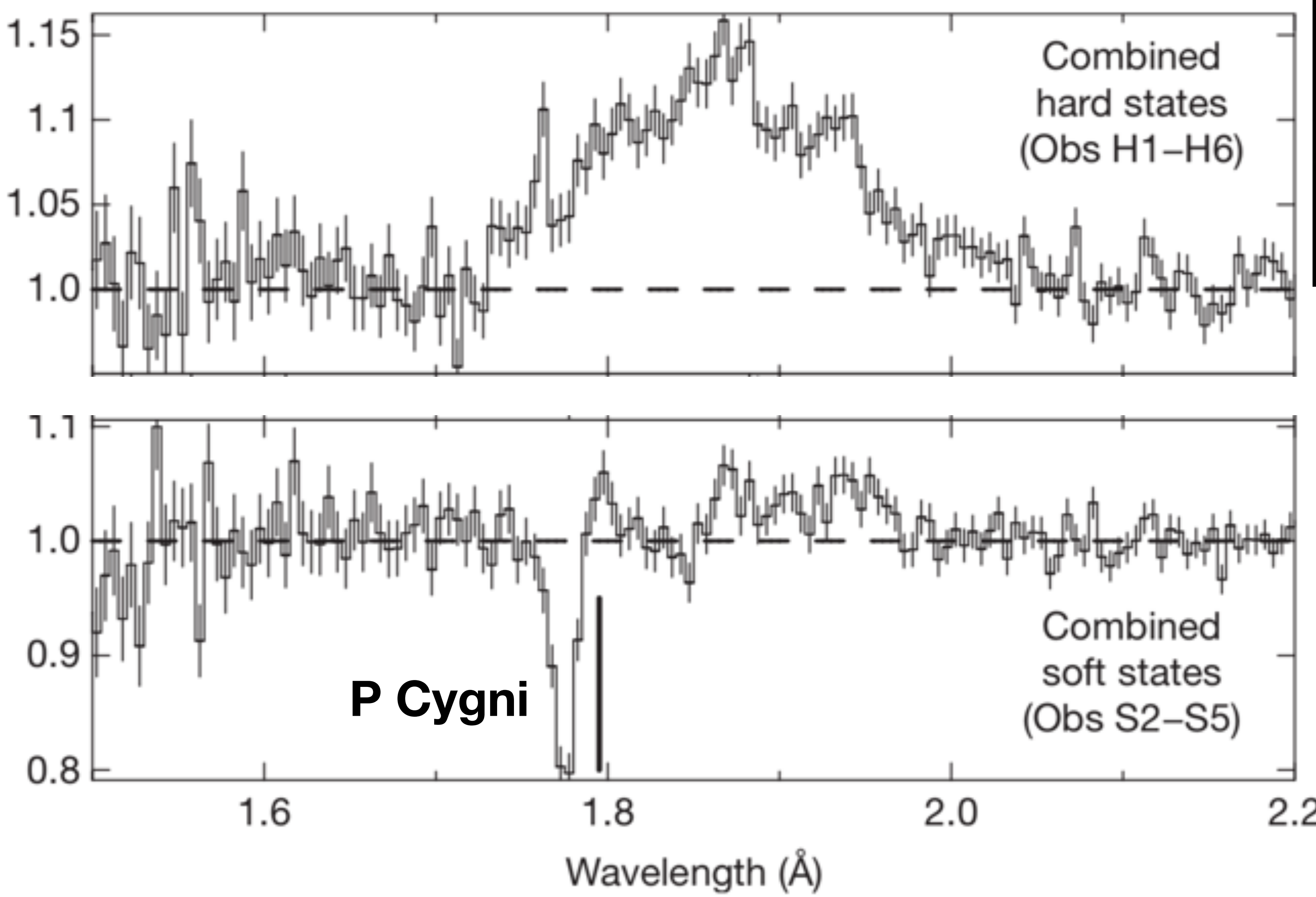


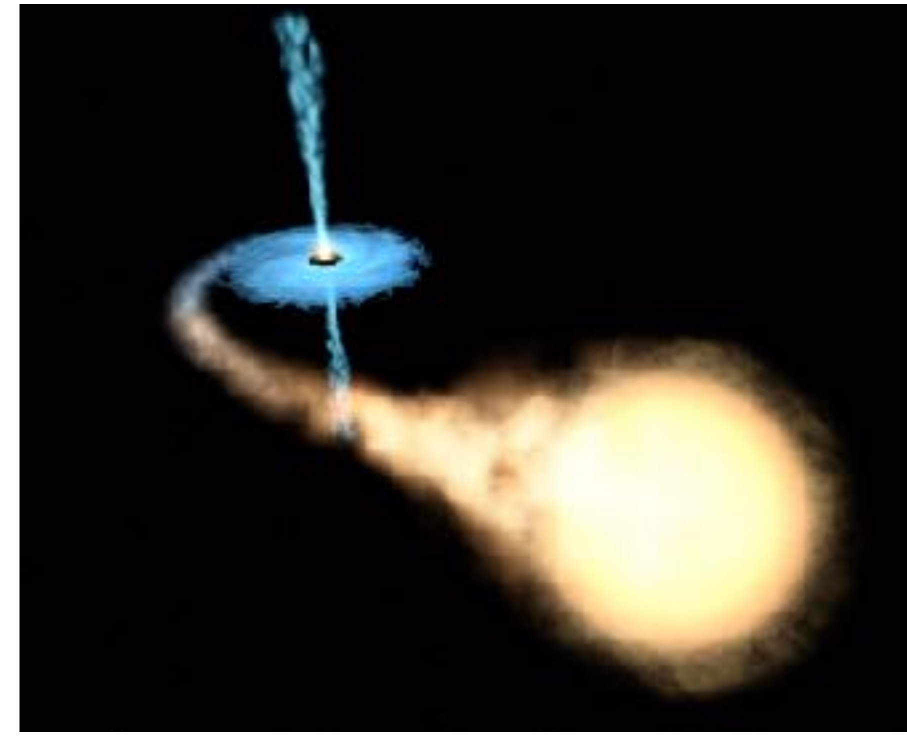

**line ratio —> T, density**

**nonequilibrium ionizing(NEI) condition**

**Accretion disk winds as the jet suppression mechanism in the microquasar GRS 1915+105**

**Neilson & Lee, 2009, nature**



**hard state —> radio jets**
**soft state —> weak jets**

**wind halts matter flowing into radio jet**

# Conclusion

1. to get a spectrum, need Mirror Assembly, Gratings, Detectors
   HRMA, LETG/HETG, ACIS/HRC in Chandra
   3 X-ray Mirror Assemblies, 2 RGSs, RFC(CCD) in XMM-Newton
2. Chandra/HETG
   —MEG: 0.023 A FWHM
   —HEG: 0.012 A FWHM
   Chandra/LETG
   —0.05 A FWHM
   XMM/RGS
   —0.06-0.07 A FWHM
3. spectroscopic ability of Gratings is more better than that of CCDs
4. lines —> composition, temperature, velocity, density…
   GRB, AGN, SNR, BH, accretion …

# Thank you!